MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 3, 2018/2019

EEE3106 – PROCESSING AND FABRICATION TECHNOLOGY
(EE)

01 JUNE 2019
9.00 a.m - 11.00 a.m
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 8 pages with 4 Questions only.
2. Attempt **ALL** questions. The distribution of the marks for each question is given.
3. Please print all your answers in the Answer Booklet provided.
4. Please refer to the APPENDIX section on pages 7 and 8 for a list of physical constants, formulas, and the error function table.

Question 1

(a) Gallium arsenide (GaAs) is a compound semiconductor for high speed integrated circuit (IC). Despite the fact that GaAs possesses higher charge carrier mobility than silicon (Si), it is the second most popular material after Si. Explain the reasons why GaAs is not as popular as Si in microelectronic fabrication.
[4 marks]

(b) Identify a crystal growth technique which requires less operator skills, and is capable of growing a doped monocrystalline semiconductor crystal with large diameter. With schematic diagram, describe the process of this crystal growth technique.
[4+8 marks]

(c) In a Czochralski (Cz) crystal growth puller, a monocrystalline Si ingot rod is pulled from the melt mixed with Si and indium (In) dopant. The Si ingot is then sliced into thin wafers. The wafer taken from the top of the boule has an In concentration of 1×10^{16} cm^{-3}. The segregation coefficient (k) for the In is given as 4×10^{-4}. Determine the doping concentration of the Si wafer taken from the position corresponding to 70 % of the initial charge solidified. What type (P-type or N type) of Si wafer is this?
[3+1 marks]

Continued …….

Question 2

(a) Photoresist (PR) is a light sensitive material, either positive or negative type, that reacts distinctively when exposed to ultraviolet (UV) light. Compliment the following characteristics of the positive and negative photoresists, respectively, given in Table 2(a). [4 marks]

Table 2(a)

Characteristics	**Negative PR**	**Positive PR**
Resolution		
Health Concern		
Environment Hazard		
Reliability		

(b) In a contact printer, a mask aligner uses an *i*-line source with a wavelength of 365 nm. If the photoresist thickness is 1 µm and the photoresist constant, k, is given as 0.7, determine the minimum feature size, W_{min}, that can be achieved using the contact printer. [2 marks]

(c) Describe the role of the etching in the fabrication of the microelectronic devices. [3 marks]

(d) Identify the three levels of interconnections in the fabrication of the integrated circuits. Give **ONE** example for these three levels of interconnections. [3 marks]

(e) Figure 2(e) presents the photolithography process for patterning a thermal oxidized silicon (Si) wafer. Prior to the UV exposure, photoresist was applied on the wafer. The thermal oxidized wafer was then exposed with UV light through the optical mask. Sketch the photoresist patterns on Si wafer, following the photoresist development processes, using positive (+PR) and negative (-PR) photoresists, respectively. [4 marks]

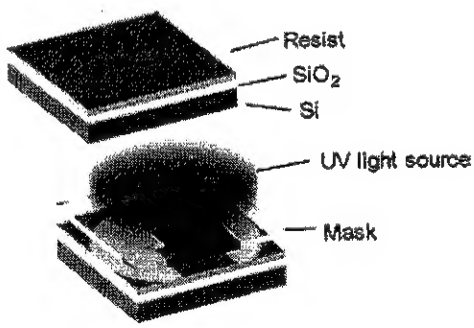

Figure 2(e): UV exposure for thermal oxidized Si wafer.

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Question 2

(f) Figure 2(f) depicts the schematic cross-section of a P-type doping on an N-type silicon wafer.

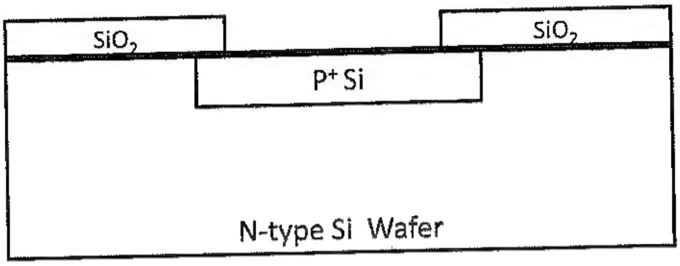

Figure 2(f): Schematic cross-section of a P-type doping on an N-type silicon wafer.

(i) Design a fabrication process flow for the structure depicted in Figure 2(f). Illustrate each processing step, starting from the N-type silicon wafer. How many level of masking process is involved in the fabrication process of the structure? [9+1 marks]

(ii) Identify a low cost and simple doping technique to form a P^+ Si well in the N-type Si wafer given in Figure 2(f). Name the component which is missing from the structure in Figure 2(f), which is required in the formation of a P-N junction diode. [4 marks]

Continued ....

Question 3

(a) Distinguish the characteristics of two types of the diffusion processes, namely, constant-source diffusion, and limited-source diffusion. [2+2 marks]

(b) In the diode structure given in Figure 2(d), boron is diffused into the N-type silicon (Si) wafer with a background doping concentration of 5×10^{16} cm^{-3}. The diffusion process is performed at 1000 °C for 30 minutes and the boron concentration at the surface is held at 2×10^{20} cm^{-3}. The diffusion coefficient for boron at 1000 °C is given by 1.45×10^{-15} cm^{2}s^{-1}. Determine the junction depth of the diode following the boron diffusion process. Is this pre-deposition diffusion or drive-in diffusion? [7+1 marks]

(c) A 30 keV implant of boron is performed onto a wafer. The projected range of the implanted profile is 3000 Å. Take the standard deviation of the projected range as 500 Å.

(i) Determine the depth of peak of the implanted profile. [1 mark]
(ii) Determine the peak concentration for dose of 10^{16} cm^{-2}. [2 marks]

(d) Describes the **FIVE** advantages of the magnetron sputtering technique over thermal evaporation technique in the deposition of the metal and metal alloys films for microelectronic device applications. [5 marks]

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Question 4

(a) Packaging is the final step after the wafer fabrication process to provide the enclosures for electronic devices. Describe the **FOUR** main functions of the packaging in microelectronic device fabrication. [4 marks]

(b) Suggest **SIX** aspects as criteria for designing a suitable package for an integrated circuit (IC). [6 marks]

(c) Identify an appropriate microelectronic package for each of the following packaging requirements:

(i) IC is operational over a wide temperature range,
(ii) IC possesses high pin density,
(iii) IC is able to be mounted/soldered/attached onto the printed circuit boards (PCBs) without requiring through-holes. [3 marks]

(d) In microelectronic production, ICs are subjected to wafer testing including electrical tests and burn-in tests. Describe the general purpose of the wafer testing. [2 marks]

(e) Thermocompression bonding uses a combination of pressure and temperature to weld a fine gold wire on the aluminum bonding pad of the die to the gold-plated lead of the package. However, thermocompression bonding may lead to the formation of a faulty gold-aluminum (Au_2Al) bond with low conductivity. Identify the root cause for this faulty bond and propose an approach to prevent the formation of this faulty bond. [6 marks]

(f) A 400 mm wafer has a defect density of 60 defects/cm^2. Each die on the wafer has a size of 5×5 mm^2. Assuming uniform defect density, determine the minimum market price for each die if the cost for testing and packaging each die is RM 3.00, while the total fabrication cost is RM 700. Propose **TWO** approaches to improve the yield of the dice. [7+2 marks]

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APPENDIX

Physical Constants:

Avogadro number, $N_{avo} = 6.02217\times10^{23}$ mol^{-1}
Boltzmann constant, $k = 1.380622\times10^{-23}$ J K^{-1} = 8.61712×10^{-5} eV K^{-1}
Electronic charge, $e = 1.60219\times10^{-19}$ C
Electron rest mass, $m_o = 9.10956\times10^{-31}$ kg
Electron volt, 1 eV = 1.60219×10^{-19} J
Si yield strength = 2×10^{7} dynes cm = 7 GPa
Latent heat of fusion for Si, L = 340 cal g^{-1}
Thermal conductivity of Si, k = 0.21 W cm^{-1} °C^{-1}
Amount of heat of 1 calorie = 4.14 J
Density of bulk Si = 2.33 g cm^{-3}
Density of molten Si = 2.53 g cm^{-3}
Electric current of 1 A = 1 Cs^{-1}
Atomic mass unit of 1 amu = 1.66053×10^{-27} kg
Magnetic flux density of 1 T = 1 Wb m^{-2} = 10^4 G
Angstrom unit of 1 Å = 1×10^{-10} m = 0.1 nm = 1×10^{-4} μm
Permittivity of free space = 8.85×10^{-14} F cm^{-1}
Pressure of 1 Torr = 133.32237 Pa

Formulas:

$C = kC_O(1-x)^{k-1}$	$C_S = \dfrac{Q_T}{\sqrt{\pi D t}}$
$\boldsymbol{\sigma = pq\mu}$	$N(x) = \dfrac{Q_O}{\sqrt{2\pi}\Delta R_P} e^{\left[\frac{-1}{2}\left(\frac{x-R_P}{\Delta R_P}\right)^2\right]}$
$\boldsymbol{W_{min} = \sqrt{k\lambda g}}$ $W_{min}=K\{\lambda/NA\}$	$N(Rp) = \dfrac{Q_O}{\sqrt{2\pi}\Delta R_P}$
$C(x,t) = C_S\, erfc\left[\dfrac{x}{2\sqrt{Dt}}\right]$	$Y = \left[\dfrac{1-e^{-D_O A}}{D_O A}\right]^2$
$Q = 2C_S\sqrt{\dfrac{Dt}{\pi}}$	$Y = \left[\dfrac{1-e^{-2D_O A}}{2D_O A}\right]$
$C(x,t) = \dfrac{Q_T}{\sqrt{\pi D t}} e^{-\frac{x^2}{4Dt}}$	$N = \dfrac{\pi(r-S)^2}{S^2}$
$x_j = 2\sqrt{Dt \ln\dfrac{C_S}{C_B}}$	$Y = e^{-D_O A}$
$x_j = 2\sqrt{Dt}\,\ln(N_0/N_B)$	$x_j = 2\sqrt{Dt}\, erfc^{-1}(N_B/N_0)$

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Values of the error function $\operatorname{erf}(t) = \frac{2}{\sqrt{\pi}} \int_0^t e^{-a^2} da$

t	0	1	2	3	4	5	6	7	8	9
0.0	0.000	0.0113	0.0226	0.0338	0.0451	0.0564	0.0676	0.0789	0.0901	0.1013
0.1	0.1125	0.1236	0.1348	0.1459	0.1569	0.1680	0.1790	0.1900	0.2009	0.2118
0.2	0.2227	0.2335	0.2443	0.2550	0.2657	0.2763	0.2869	0.2974	0.3079	0.3183
0.3	0.3286	0.3389	0.3491	0.3593	0.3694	0.3794	0.3893	0.3992	0.4090	0.4187
0.4	0.4284	0.4380	0.4475	0.4569	0.4662	0.4755	0.4847	0.4937	0.5027	0.5117
0.5	0.5205	0.5292	0.5379	0.5465	0.5549	0.5633	0.5716	0.5798	0.5879	0.5959
0.6	0.6039	0.6117	0.6194	0.6270	0.6346	0.6420	0.6494	0.6566	0.6638	0.6708
0.7	0.6778	0.6847	0.6914	0.6981	0.7047	0.7112	0.7175	0.7238	0.7300	0.7361
0.8	0.7421	0.7480	0.7538	0.7595	0.7651	0.7707	0.7761	0.7814	0.7867	0.7918
0.9	0.7969	0.8019	0.8068	0.8116	0.8163	0.8209	0.8254	0.8299	0.8342	0.8385
1.0	0.8472	0.8468	0.8508	0.8548	0.8586	0.8624	0.8661	0.8698	0.8733	0.8768
1.1	0.8802	0.8835	0.8868	0.8900	0.8931	0.8961	0.8991	0.9020	0.9048	0.9076
1.2	0.9103	0.9130	0.9155	0.9181	0.9205	0.9229	0.9252	0.9275	0.9297	0.9319
1.3	0.9340	0.9361	0.9381	0.9400	0.9419	0.9438	0.9456	0.9473	0.9490	0.9507
1.4	0.9523	0.9539	0.9554	0.9569	0.9583	0.9597	0.9611	0.9624	0.9637	0.9649
1.5	0.9661	0.9673	0.9684	0.9695	0.9706	0.9716	0.9726	0.9736	0.9746	0.9755
1.6	0.9764	0.9772	0.9780	0.9789	0.9796	0.9804	0.9811	0.9818	0.9825	0.9832
1.7	0.9838	0.9844	0.9850	0.9856	0.9861	0.9867	0.9872	0.9877	0.9882	0.9886
1.8	0.9891	0.9895	0.9899	0.9904	0.9907	0.9911	0.9915	0.9918	0.9922	0.9925
1.9	.99279	.99309	.99338	.99366	.99392	.99418	.99443	.99466	.99489	.99511
2.0	.99532	.99552	.99572	.99591	.99609	.99626	.99642	.99658	.99673	.99688
2.1	.99702	.99715	.99728	.99741	.99753	.99764	.99775	.99785	.99795	.99805
2.2	.99814	.99822	.99831	.99839	.99846	.99854	.99861	.99867	.99874	.99880
2.3	.99886	.99891	.99897	.99902	.99906	.99911	.99915	.99920	.99924	.99928
2.4	.99931	.99935	.99938	.99941	.99944	.99947	.99950	.99952	.99955	.99957
2.5	.99959	.99961	.99963	.99965	.99967	.99969	.99971	.99972	.99974	.99975
2.6	.99976	.99978	.99979	.99980	.99981	.99982	.99983	.99984	.99985	.99986
2.7	.99987	.99987	.99988	.99989	.99989	.99990	.99991	.99991	.99992	.99992
2.8	.99992	.99993	.99993	.99994	.99994	.99994	.99995	.99995	.99995	.99996
2.9	.99996	.99996	.99996	.99997	.99997	.99997	.99997	.99997	.99997	.99998
3.0	.99998	.99998	.99998	.99998	.99998	.99998	.99998	.99999	.99999	.99999

for $t > 3$ $\quad \operatorname{erf}(t) \approx 1 - \frac{1}{\sqrt{\pi}\, t} \exp\left(-t^2\right)$

erfc (t) = 1 - erf (t)

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